

## A revision of the *Calytrix acutifolia* complex (Myrtaceae: Chamelaucieae)

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### Abstract

Nge, F.J., Keighery, G.J. & Thiele, K.R. A revision of the *Calytrix acutifolia* complex (Myrtaceae: Chamelaucieae). *Nuytsia* 28: 321–337 (2017). In this taxonomic review of the *Calytrix acutifolia* (Lindl.) Craven species complex we recognise four species, one of which (*C. retrorsifolia* Nge & Keighery) is described as new. *Lhotskya hirta* Regel is recombined into *Calytrix* Labill. as *C. hirta* (Regel) Nge & K.R.Thiele, while *L. scabra* Turcz. is recombined as *C. cravenii* Nge & K.R.Thiele. *Calytrix acutifolia* s. str. is recircumscribed as the fourth member of the complex.

### Introduction

*Calytrix* Labill. is an endemic Australian genus comprising c. 90 species distributed throughout Australia, with centres of species richness in northern and south-western Australia (Craven 1987). The most recent revision of the genus was completed by Craven (1987), following which nine new species have been described and named by various authors (Craven 1990, 1991; Keighery 2004; Barrett *et al.* 2009; Rye 2013). Six informal phrase-named taxa belonging to two species complexes within the genus are currently recognised in Western Australia (Western Australian Herbarium 1998–); four of these are assigned to the *C. acutifolia* (Lindl.) Craven species complex (Rye 2013).

*Calytrix acutifolia* was described (as *Lhotskya acutifolia* Lindl.) in 1839, with no type cited. Craven (1987) followed Mueller (1859) and Court (1957) in regarding *Calytrix* and *Lhotskya* Schauer as congeneric, formally transferring all species of the latter into the former. He reduced three species of *Lhotskya* (*L. ericoides* Schauer, *L. scabra* Turcz. and *L. hirta* Regel) to synonyms of *C. acutifolia*, recognising it as a single, variable and wide-ranging species distributed from the Arrowsmith River southward to Albany and east to Cape Arid. He placed *C. acutifolia* provisionally in a small informal group of five species (the '*C. violacea* (Lindl.) Craven group', characterised by 2–4-seriate stamens and a hypanthium not produced above the ovary), but regarded it as anomalous within that group on account of some features shared with the eastern Australian *C. glaberrima* (F.Muell.) Craven and the widespread *C. tetragona* Labill. in the *C. tetragona* group (characterised by a 1-seriate androecium). None of Craven's species groups were formally named, and relationships of species within *Calytrix* have not been tested in an explicitly phylogenetic framework.

Preliminary assessment of field and herbarium specimens by one of us (GK) in 2001 led to the segregation from *C. acutifolia* of four informal, phrase-named taxa: *C. sp. Eneabba* (B.J. Lepschi & T.R. Lally BJL3617), *C. sp. Scarp* (H. Bowler 270), *C. sp. Tutunup* (G.J. Keighery & N. Gibson 2953) and *C. sp. Wheatbelt* (R. Davis 4544) (Western Australian Herbarium 1998–). At that time, *C. acutifolia s. str.* was regarded as comprising specimens from the south coast of Western Australia between Cape Naturaliste and Bremer Bay, inland to the Stirling Range. A re-examination of type specimens by B. Rye (pers. comm.) subsequently led to the recognition that *C. sp. Scarp* represents *C. acutifolia s. str.*, with specimens previously assigned to *C. acutifolia* placed under the informal name *C. sp. Esperance* (M.A. Burgman 4268A).

*Calytrix sp. Esperance* was further separated in the collection at the Western Australian Herbarium (PERTH), though without formal phrase-naming, into an eastern and western morphotype (east and west of Bremer Bay respectively) by one of us (GK) based on differences in leaf dimensions, the western form having longer and narrower leaves than the eastern form. Within *C. sp. Wheatbelt*, a group of collections from near Calingiri with unusually short leaves was tentatively segregated (by GK) from *C. sp. Wheatbelt*, but was not recognised as distinct by Rye (2013).

The present paper is the result of a detailed examination of all specimens in the *C. acutifolia* species complex held at PERTH, of images of relevant type specimens available through *Global Plants* (<https://plants.jstor.org>), and of type material held at KW, to ascertain taxon boundaries within the complex.

## Methods

Preliminary assessment of herbarium material confirmed that there is considerable variation in leaf dimensions among taxa within the *C. acutifolia* complex, particularly between the eastern and western forms of *C. sp. Esperance*, and within *C. sp. Wheatbelt* and *C. sp. Eneabba*. To assess this variation quantitatively, lengths and widths of leaves were measured, and length:width ratios calculated, from representative herbarium specimens across all taxa within the complex. Three mature leaves per specimen were measured with a digital caliper to the nearest 0.01 mm; average values were then calculated for each measured specimen.

To assess the influence of climate on variations in leaf dimensions across the distributional ranges of members within the complex, locations of specimens examined were uploaded into the Spatial Portal of the Atlas of Living Australia (ALA; <http://www.ala.org.au>), and mean annual aridity index (AI) values retrieved. Correlations between AI and leaf dimensions were assessed using the R statistics package (R Core Team 2016).

The distribution map is based on PERTH specimens only, and shows the *Interim Biogeographic Regionalisation for Australia* (IBRA) v. 7 bioregions (Department of the Environment 2013).

## Results and Discussion

Detailed assessment of floral and vegetative characters revealed consistent differences between some but not all putative taxa in the *C. acutifolia* complex. Four morphologically discrete forms were readily separable (Table 1). Characters that are taxonomically useful include hypanthium morphology, bracteole (cheridium) shape, calyx and corolla size, leaf arrangement, indumentum, shape in transverse section (TS), and apex shape.

A combination of these characters adequately discriminates *C. acutifolia*, *C. sp.* Esperance and *C. sp.* Tutunup. Several characters distinguish *C. sp.* Eneabba and *C. sp.* Wheatbelt from the other members within the complex; however, no consistent differences were found to separate these two from each other.

**Table 1.** Morphological comparison of taxa in the *Calytrix acutifolia* species complex.

Character	<i>C. acutifolia</i>	<i>C. sp.</i> Esperance	<i>C. sp.</i> Tutunup	<i>C. sp.</i> Wheatbelt	<i>C. sp.</i> Eneabba
<b>Indumentum</b>	present on stems only (leaves, hypanthium and bracteoles glabrous)	present on stems, leaves, hypanthium and bracteoles	present on stems, leaves and bracteoles (hypanthium glabrous)	present on stems, leaves, hypanthium and bracteoles	present on stems, leaves, hypanthium and bracteoles
<b>Stem hair length (mm)</b>	0.05–2	0.1–0.5	0.1–0.5	0.05–0.15(–0.2)	0.05–0.15(–0.2)
<b>Leaf hair length (mm)</b>	absent	≤ 0.05	≤ 0.05	0.05–0.2	0.05–0.2
<b>Leaf arrangement on stems</b>	usually antrorse, rarely patent at maturity	mostly patent at maturity	reflexed at maturity	mostly antrorse at maturity (leaves appressed in the Calingiri form)	mostly antrorse at maturity
<b>Leaf length (mm)</b>	8.6–12.6	3–11	3.7–7.3	2.7–9.2	4–10.5
<b>Leaf length:width ratio</b>	7.4–26.3	5–28.5	7.7–17.8	5.1–21.0	8.7–14.2
<b>Leaf transverse section</b>	depressed-triangular with concave adaxial surface	depressed-angular-obovate	depressed-angular-obovate	depressed-triangular	depressed-triangular
<b>Protruding midrib on abaxial surface</b>	present	absent	absent	absent	absent
<b>Translucent wings on bracteoles (cheridium)</b>	broad and overlapping to apex, covering > 3/4 of the hypanthium	reduced, scarcely overlapping (hypanthium clearly visible)	reduced, scarcely overlapping (hypanthium clearly visible)	reduced, with hypanthium clearly visible to wings that extend and overlap to the mid-point, covering c. 1/2 of the hypanthium	reduced, with hypanthium clearly visible to wings that extend and overlap to the mid-point, covering c. 1/2 of the hypanthium
<b>Hypanthium</b>	5–7-ribbed, smooth between the ribs	mostly 6–8-ribbed, smooth or rarely rugose between the ribs	5-ribbed, prominently rugose between the ribs	5-ribbed, smooth or rugose-pitted between the ribs	5-ribbed, smooth between the ribs
<b>Hypanthium length (mm)</b>	3.5–4.5	(2–)2.5–3.5	1.5–2	1.7–4	2.5–4
<b>Petal length (mm)</b>	7.5–10	4–5.5(–7)	4–5	4–7	6–7
<b>Petal width (mm)</b>	2–2.5	0.8–1.5	0.5–1.3	1.5–1.7	1.5–1.7
<b>Number of stamens</b>	40–85	32–46	23–40	18–50	18–50

Leaf dimensions (length, width, length:width ratio) within the complex overlap significantly, and were not found to be taxonomically useful, except that *C. acutifolia* has longer and wider leaves than other members within the complex (Figure 1). Within *C. sp. Esperance*, the eastern morphotype has shorter and wider leaves than the western variant (Figure 1). Patterns of variation in leaf length and width in *C. sp. Esperance* are geographically correlated (Figure 2); specimens that are geographically intermediate between the two morphotypes have leaves that are intermediate in leaf dimensions. Leaves in general are shortest and widest at the easternmost end of its distribution, and longest and narrowest at the westernmost end, with the exception of plants from near Cape Leeuwin that have shorter and

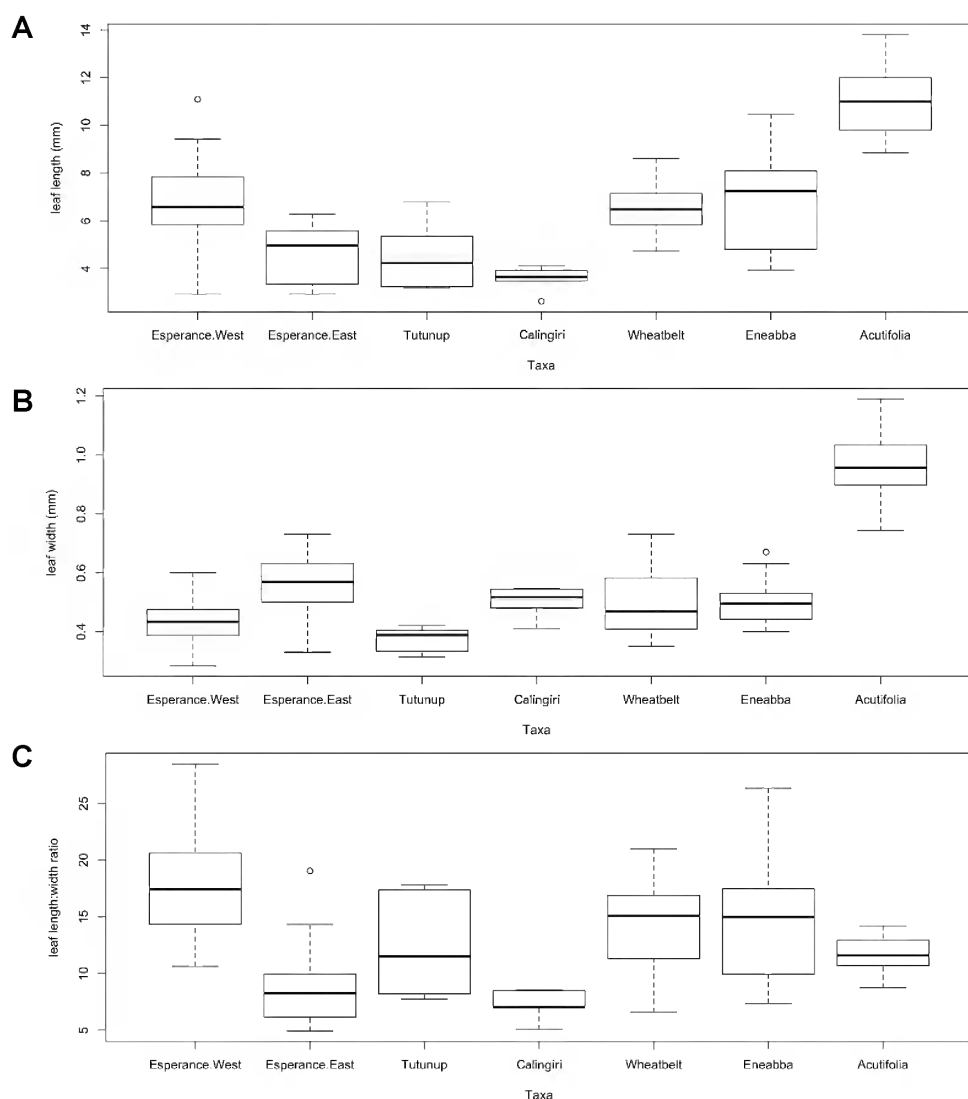


Figure 1. Variation in leaf morphology of members within the *Calytrix acutifolia* complex based on herbarium specimens examined in PERTH. A – leaf length (mm); B – leaf width (mm); C – leaf length:width ratio. Rectangles define 25 and 75 percentiles; horizontal lines show median; whiskers are from 10 to 90 percentiles; circles indicate outliers. Taxon names ‘Esperance.West’ and ‘Esperance.East’ refer to the two respective variants of *C. sp. Esperance* (M.A. Burgman 4268A), and ‘Calingiri’ refers to the Calingiri form of *C. sp. Wheatbelt* (R. Davis 4544).



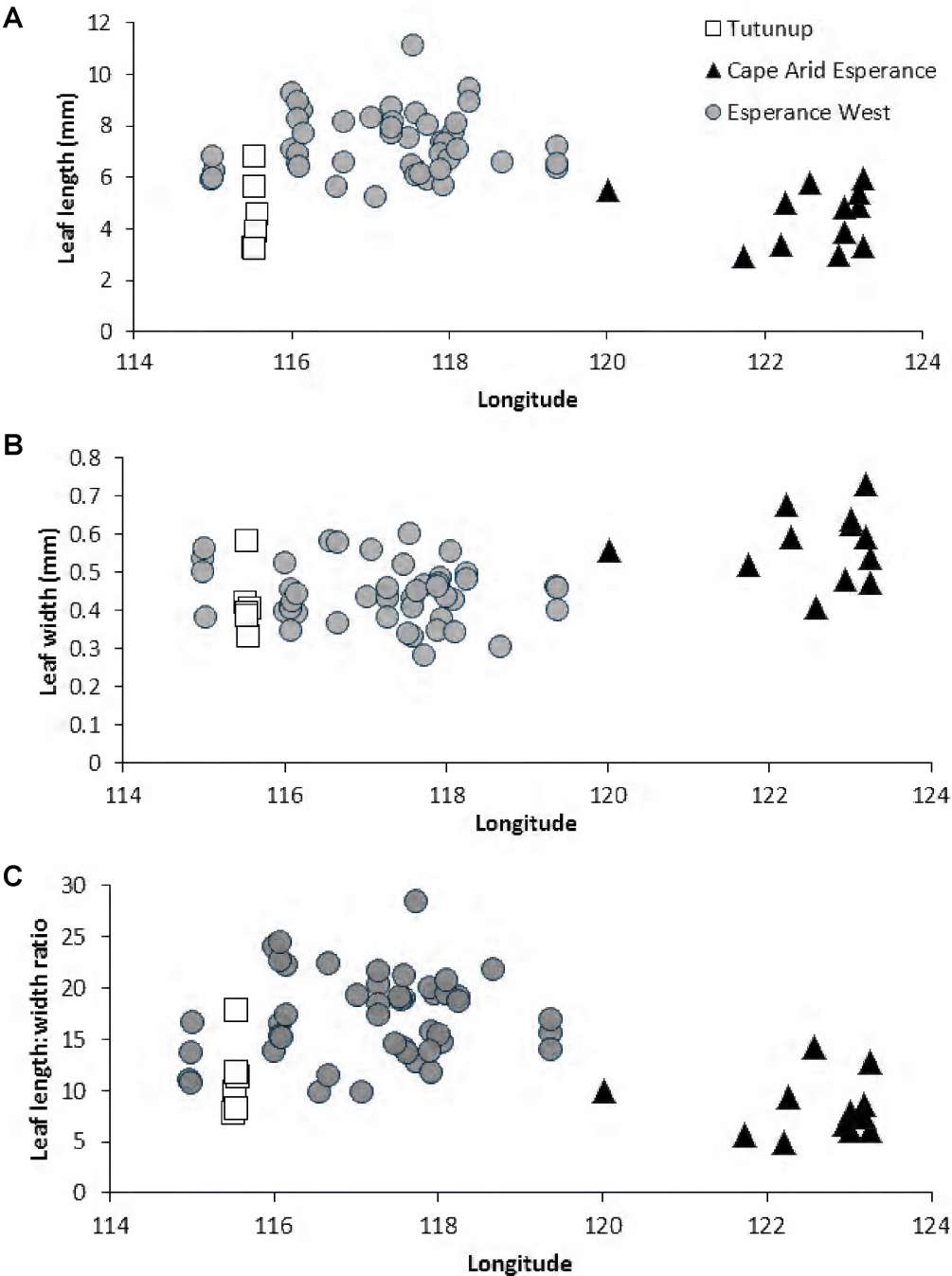


Figure 2. Variation in leaf morphology of *Calytrix* sp. Esperance (M.A. Burgman 4268A) and *C.* sp. Tutunup (G.J. Keighery & N. Gibson 2953) against geographic locality (as longitude) of specimens examined in PERTH. A – leaf length (mm); B – leaf width (mm); C – leaf length:width ratio. Taxon names ‘Cape Arid Esperance’ and ‘Esperance West’ refer to the two respective variants of *C.* sp. Esperance.

wider leaves than other specimens of the western morphotype. The overall pattern in leaf dimensions correlates significantly ( $p < 0.05$ ) with mean annual aridity index (AI; Table 2). The Cape Leeuwin plants, which do not conform to this trend, were collected from near-coastal sites and are likely to be short-leaved due to the influence of the coastal environment. *Calytrix* sp. Tutunup has leaves more similar to the eastern than the geographically closer western variant of *C. sp. Esperance* (Figure 2).

There is significant overlap in leaf dimensions between *C. sp. Eneabba* and *C. sp. Wheatbelt*, although the northernmost populations of *C. sp. Eneabba* have longer leaves than the rest (Figure 3). The Calingiri form of *C. sp. Wheatbelt* occurs at the boundary between the two putative taxa, and has much shorter leaves than either. Variations in leaf morphology were not significantly correlated with AI ( $p > 0.05$ ), with the exception of leaf width ( $p < 0.05$ ; Table 2). However, the correlation was non-significant ( $p > 0.05$ ) once a suspected outlier population (Collie; PERTH 02157195) was removed from the analysis. A separate analysis of *C. sp. Wheatbelt* alone showed significant correlation ( $p < 0.05$ ) of both leaf length and length:width ratio with AI (Table 2). However, these differences were non-significant ( $p > 0.05$ ) when the Calingiri form was excluded from the analysis.

**Table 2.** Pairwise t-test summary results: relationship between leaf morphology and associated aridity indices and geographic coordinates. Note: \*, \*\* and \*\*\* represent significance levels of  $p < 0.001$ , 0.01 and 0.05 respectively.

Taxon	Leaf characters	Aridity index	p-value	
			Longitude	Latitude
<b><i>C. sp. Esperance</i></b>	length (mm)	3.24e-05 ***	5.93e-05 ***	0.0421 *
	width (mm)	0.01094 *	0.00082 ***	0.14918
	length:width ratio	7.37e-05 ***	5.24e-05 ***	0.0276 *
<b><i>C. sp. Wheatbelt–sp. Eneabba</i></b>	length (mm)	0.99981	0.00120 **	0.00474 **
	width (mm)	0.018249 *	0.740013	0.000473 ***
	length:width ratio	0.4804	0.0117 *	1.77e-05 ***
<b><i>C. sp. Wheatbelt–sp. Eneabba (excluding Collie outlier)</i></b>	length (mm)	0.245968	0.000517 ***	0.037543 *
	width (mm)	0.64861	0.93311	0.00145 **
	length:width ratio	0.38859	0.00535 **	0.00015 ***
<b><i>C. sp. Wheatbelt</i></b>	length (mm)	0.0031 **	0.2751	0.635
	width (mm)	0.5233	0.1132	0.0299 *
	length:width ratio	0.0303 *	0.0436 *	0.1703
<b><i>C. sp. Wheatbelt (excluding Calingiri form)</i></b>	length (mm)	0.0746	0.2102	0.2292
	width (mm)	0.5709	0.1015	0.0365 *
	length:width ratio	0.524	0.586	0.226
<b><i>C. sp. Eneabba</i></b>	length (mm)	0.6957	1.23e-06 ***	0.0235 *
	width (mm)	0.9297	0.0312 *	0.8966
	length:width ratio	0.697	3.85e-07 ***	0.0114 *

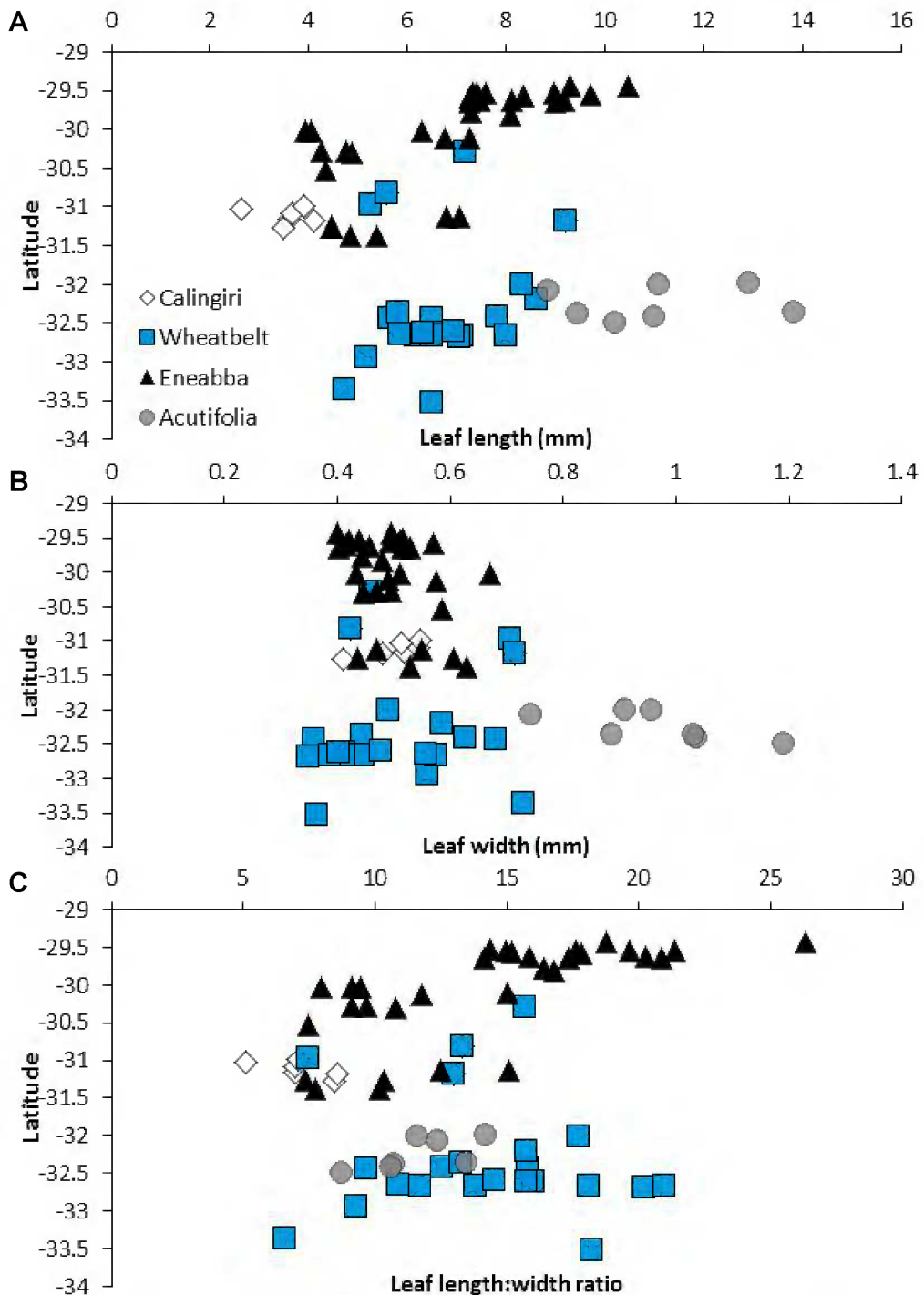


Figure 3. Variation in leaf morphology of *Calytrix acutifolia*, *C. sp.* Eneabba (B.J. Lepschi & T.R. Lally BJL3617) and *C. sp.* Wheatbelt (R. Davis 4544) against geographic locality (as latitude) of specimens examined in PERTH. A – leaf length (mm); B – leaf width (mm); C – leaf length:width ratio. Taxon name ‘Calingiri’ refers to the Calingiri form of *C. sp.* Wheatbelt.

In summary, of the seven currently recognised potential taxa in the *C. acutifolia* complex (including two variants of *C. sp. Esperance* and the Calingiri form of *C. sp. Wheatbelt*), four taxa are supported by this analysis based on clear and consistent morphological differences in indumentum, leaf, bracteole, hypanthium and floral characters. *Calytrix sp. Wheatbelt* and *C. sp. Eneabba* are not supported as distinct from each other, and are here combined into a single taxon; the Calingiri variant of this taxon is unusual in leaf dimensions but is otherwise typical. The eastern and western variants of *C. sp. Esperance* comprise two ends of a geographic cline, probably caused by increasing aridity towards the eastern end of the range of the taxon (with unusually short-leaved individuals from near Cape Leeuwin probably resulting from near-coastal environmental conditions).

Since the four recognised taxa show consistent and non-overlapping morphological differences, species rank is assigned to them here. All four taxa are allopatric.

### Key to species of the *Calytrix acutifolia* complex

1. Bracteoles with translucent wings that extend and overlap to the apex, covering  $> 3/4$  the length of the hypanthium; corolla 7.5–10 mm long; leaf blades 0.6–1.1 mm wide, with a distinct, protruding adaxial midrib, depressed-triangular in TS with a concave adaxial surface (Lesmurdie–Oakley)..... ***C. acutifolia***
- 1: Bracteoles with translucent wings reduced, the hypanthium clearly visible, or with translucent wings that extend and overlap for  $< 1/2$  the length of the hypanthium; corolla  $< 7$  mm long; leaf blades  $< 0.6$  mm wide, lacking a protruding adaxial midrib, depressed-triangular to obovate in TS..... **2**
2. Leaf blades obtriangular to depressed-obtriangular in TS, glabrous to prominently ciliate on margins, the hairs 0.05–0.2 mm long; stems with hairs 0.05–0.15(–0.2) mm long (Dongara–Narrogin)..... ***C. cravenii***
- 2: Leaf blades depressed-angular-obovate in TS, glabrous to sparsely ciliate on margins, the hairs to 0.05 mm long; stems with hairs 0.2–0.5 mm long ..... **3**
3. Hypanthium (2–)2.5–3.5 mm long, mostly 6–8-ribbed, smooth to somewhat rugose between the ribs; leaves patent at maturity (Yallingup–Esperance)..... ***C. hirta***
- 3: Hypanthium 1.5–2 mm long, 5-ribbed, markedly rugose between the ribs; leaves reflexed at maturity (Busselton–Tutunup)..... ***C. retrorsifolia***

### Taxonomy

***Calytrix acutifolia*** (Lindl.) Craven, *Brunonia* 10(1): 122–123 (1987). *Lhotskya acutifolia* Lindl., *Sketch Veg. Swan R.* 7 (1839). *Type*: [not cited] Swan River [Western Australia], 1839 [1835–1838], *J. Drummond s.n. (lecto: CGE, designated by L.A. Craven, Austral. Syst. Bot.* 10: 122 (1987); *isolecto: G 00227522 image!*, *G 00227546 image!*; *K 000821951 image!*).

*Calytrix sp.* Scarp (H. Bowler 270), Western Australian Herbarium, in *FloraBase*, <https://florabase.dpaw.wa.gov.au/> [accessed 14 December 2016].

Erect, open *shrubs* 0.6–2 m high. *Young stems* abundantly pilose with hairs 0.05–2 mm long, red-brown on new growth, with prominent leaf scars on older stems. *Leaves* alternate to partially subopposite; foliar colleters absent; petioles 1–1.2 mm long, yellow, glabrous; blades linear, 8.6–12.6 mm long, 0.6–1.1 mm wide, depressed-triangular in TS with a concave adaxial surface and distinct midrib protruding from the abaxial surface, glabrous; oil glands obscure to sometimes prominent; apex acute to acuminate. *Inflorescences* 20–130 mm long, 5–10 mm below shoot apex; peduncles 1–1.5 mm long,

glabrous to ciliate, slightly extended between bracteoles at apex; bracteoles green to light brown, glabrous, 4–5 mm long, free or slightly connate at base, with entire margins and long-acuminate apex, prominently translucent-winged with the wings overlapping and as long as the hypanthium. *Flowers* 5-merous, 15.5–16.7 mm diam.; hypanthium 5–7-ribbed, subcylindrical, 3.5–4.5 mm long, glabrous, smooth between the ribs; sepals 1–2.3 mm long, 1–1.5 mm wide, glabrous, the margin entire to slightly erose, the apex emarginate to obtuse-truncate, lacking awns; petals 7.5–10 mm long, 2–2.5 mm wide, white (pale yellow in bud), glabrous; staminodes absent; stamens 40–85, white, 2–4-seriate, the longest filaments 5–7 mm long, the anthers *c.* 0.3 mm long, cream to light yellow; style 6.5–7.5 mm long, white. *Seed* not seen. (Figure 4A)

*Selected specimens examined.* WESTERNAUSTRALIA: Serpentine, between Perth and Pinjarra, Nov. 1899, *C. Andrews s.n.* (PERTH); Mills Rd, 0.5 km E of Metro Water Supply access road, Gosnells, 2 Nov. 1979, *R.J. Cranfield* 984/79 (PERTH); Gooseberry Hill, Darling Range, 21 Oct. 1897, *R. Helms s.n.* (PERTH); Serpentine National Park, *c.* 750 m ESE of Chatfield Rd on upper slope below granite, 31 Oct. 1996, *A. Markey* 495 (PERTH); Lesmurdie National Park, Falls Rd, Lesmurdie, NW of carpark 30 m, N of walking track, 9 Dec. 1996, *A. Markey* 923 (PERTH); Bodhinyana Monastery, 216 Kingsbury Drive, Serpentine, 12 Oct. 2002, *B. Nyanatusita* 262 (PERTH); Oakley Dam, *c.* 300 m W of dam wall, 17 Nov. 1992, *S. Patrick* 1401 (PERTH); 45 miles out Brookton Hwy, 27 Sep. 1959, *L. Steenbohm s.n.* (PERTH).

*Phenology.* Flowers from September to November, with a peak from mid-October to early November.

*Distribution and habitat.* Confined to the escarpment of the Darling Range and adjacent foothills of the Pinjarra Plain, from Helena Valley to Oakley Dam (Figure 5). Populations are restricted to two main centers along the escarpment, one east of Perth and the other in Oakley. A disjunct collection (*L. Steenbohm s.n.*) is from *c.* 50 km east of the main distribution, along the Brookton Highway; it is morphologically typical. Grows on hill slopes and gullies over granite, in lateritic gravel, clay, and/or gritty loam, in wandoo and marri woodlands, with understorey species including *Grevillea endlicheriana*, *Hakea undulata*, *Trymalium ledifolium*, *Darwinia citriodora* and *Acacia pulchella*.

*Conservation status.* *Calytrix acutifolia* is restricted in range but is not considered to be at risk. Over half of the populations are found in national parks and nature reserves.



Figure 4. Hypanthium and bracteole structure of the four study species. A – *Calytrix acutifolia* (PERTH 06739822); B – *C. cravenii* (PERTH 07213751); C – *C. retrorsifolia* (PERTH 06062059); D – *C. hirta* (PERTH 01955117). Scale bar = 4 mm.

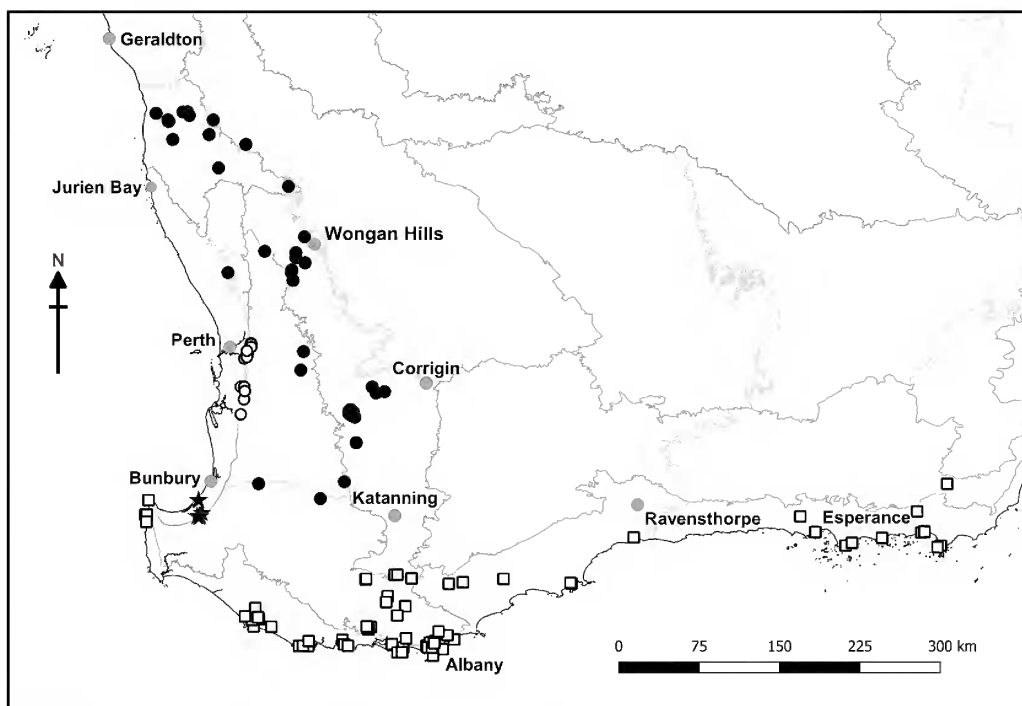


Figure 5. Distribution of *Calytrix acutifolia* (○), *C. hirta* (□), *C. retrorsifolia* (★), and *C. cravenii* (●) in south-west Western Australia.

*Notes.* *Calytrix acutifolia* is the most distinctive member of the complex, differing from all others by its larger leaves (0.6–1.1 mm wide and to 12.6 mm long) and flowers (7.5–10 mm long). Its leaves, hypanthium, and bracteoles are always glabrous, while all other members of the complex have an indumentum on some or all of these parts. In addition, its bracteoles have prominent translucent wings that extend and overlap to the bracteole apex (and hence cover most of the hypanthium), while other species have narrower wings that overlap to a lesser extent, with the upper half or more of the hypanthium exposed. It is the only species in the complex that occurs on the escarpment of the Darling Range.

***Calytrix cravenii* Nge & Thiele, *nom. nov.***

*Lhotskyia scabra* Turcz., *Bull. Soc. Imp. Naturalistes Moscou* II. 324 (1862). *Type*: ‘Nova Hollandia. Gilbert n. 186.’ (*lecto*: KW 1001262 image!, inadvertently designated by L. Craven, *Austral. Syst. Bot.* 10: 122 (1987); *isolecto*: K 821950 image!).

*Calytrix* sp. Eneabba (B.J. Lepschi & T.R. Lally BJL3617), Western Australian Herbarium, in *FloraBase*, <https://florabase.dpaw.wa.gov.au/> [accessed 14 December 2016].

*Calytrix* sp. Wheatbelt (R. Davis 4544), Western Australian Herbarium, in *FloraBase*, <https://florabase.dpaw.wa.gov.au/> [accessed 14 December 2016].

Erect, open *shrubs* 0.5–2 m high. *Young stems* abundantly pilose with hairs 0.05–0.15(–0.2) mm long, mottled cream and pale brown or red-brown on new growth, with prominent leaf scars on older stems. *Leaves* alternate to partially subopposite; foliar colleters absent; petioles 0.5–1 mm long,



yellow, glabrous to ciliate; blades linear to linear-oblongate, 3–11 mm long, 0.3–0.9 mm wide, depressed-triangular in TS, glabrous to prominently ciliate with hairs 0.05–0.2 mm long; oil glands usually absent, sometimes noticeable; apex acute to obtuse. *Inflorescences* 20–100 mm long, 2–10 mm below shoot apex; peduncles 0.5–0.8 mm long; bracteoles green to light brown, ciliate along midrib, 2–3.5 mm long, free and sparingly connate at base, with entire margins and long-acuminate apex, translucent wings reduced and scarcely overlapping. *Flowers* 5-merous, *c.* 10–15 mm diam.; hypanthium 5-ribbed, subcylindrical, (1.7–)2.5–4 mm long, smooth or rugose-pitted between the ribs, glabrous to finely ciliate, with two rows of hairs present along each rib; sepals 0.6–1.1 mm long, 0.2–0.8 mm wide, glabrous, the margin erose, the apex obtuse-truncate, lacking awns; petals (4–)6(–7) mm long, 1.5–1.7 mm wide, white (pale yellow in bud), glabrous; staminodes absent; stamens 18–29, white, 2-seriate, the longest filaments 4–5 mm long, the anthers 0.2–0.3 mm long; style (4–)5–6 mm long, white. *Seed* not seen. (Figure 4B, 6A)

*Diagnostic features.* The following combination of characters can be used to differentiate *C. cravenii* from other species within the complex: leaf in transverse section depressed-triangular; leaf blades usually ciliate with prominent indumentum to 0.2 mm long (rarely glabrous); hairs along pilose stems 0.05–0.15 long; petals usually *c.* 6 mm long (Calingiri form *c.* 4 mm long); leaf blades linear to linear-oblongate.

*Other specimens examined.* WESTERN AUSTRALIA: 6.7 miles E of Carani, 30 Aug. 1971, T.E.H. Aplin 4881 (PERTH); 22.4 miles from Coorow on Green Head road, 7 Nov. 1978, C. Chapman (30)78 (PERTH); 3 km along Morawa water supply road from the Arrino West Rd, 2 Oct. 1981, L.A. Craven & C. Chapman 6843 (CANB); Duranillin–Bowelling Rd, 1 km W of Duranillin, 18 Nov. 1997, R. Davis 4544 (PERTH); road verge Prices Rd, NW of Moora, 1 Oct. 1988, E.A. Griffin 5402 (PERTH); quadrat POPO13 Landsell remnant bushland Popanyinning, 13 Nov. 1996, A.G. Gunness *et al.* POPO 13/45 (PERTH); Calingiri Water Reserve 17655/29461, Fordham Rd, Calingiri, Shire of Victoria Plains, *c.* 100 m S of the railway crossing on Fordham Rd, between road and railway line, 6 Aug. 2005, F. Hort & J. Hort FH 2568 (PERTH); Lot 4, E of Moore River National Park, 9 Oct. 2002, G.J. Keighery & N. Gibson *s.n.* (PERTH); W side of the Wongan Hills, *c.* 200 km NE of Perth, 29 Oct. 1980, K.F. Kenneally 7511 (PERTH); spring-fed creek 30 km NE of Eneabba on edge of unnamed NR A12705, E side of Skipper Rd 4 km NNE of intersection of Bunney Rd and Skipper Rd. SAP wetlands site SPS180B, 23 Sep. 1999, M.N. Lyons & S.D. Lyons 3534 (PERTH); wetland within Martinjinni NR C2736, 20 km WSW of Dalwallinu, 1.0 km NNE of SW corner of reserve on E side of road, NE side of wetland, SAP wetlands site SPS155B, 5 Oct. 1999, M.N. Lyons & S.D. Lyons 3528 (PERTH); Jingaring Nature Reserve, Jingaring road, *c.* 30 km ENE of Pingelly, 7 Nov. 1999, L.W. Sage, R. Davis & F. Obbens LWS 1328 (PERTH); Reserve 424, off West Talbot Rd, York, 16 Nov. 2001, H. Seeds 176 (PERTH).

*Phenology.* Flowers from spring to early summer (early September to early December), with a peak in October–November.

*Distribution and habitat.* Wide-ranging, found in a range of habitats in the Geraldton Sandplains and Avon Wheatbelt bioregions, from Dongara to Wongan Hills, south to Narrogin (Figure 5), commonly on sandplains (white, grey, or yellow sandy soils) with associated kwongan heath or low woodland vegetation communities. A few populations are found near riverbanks and valleys, on dry white sand or damp sandy clay along drainage lines. An outlying specimen from the Collie area (PERTH 02157195) may have been introduced with road materials, as it is well to the west of the main distribution and is the only collection known to occur in the Jarrah Forest bioregion.



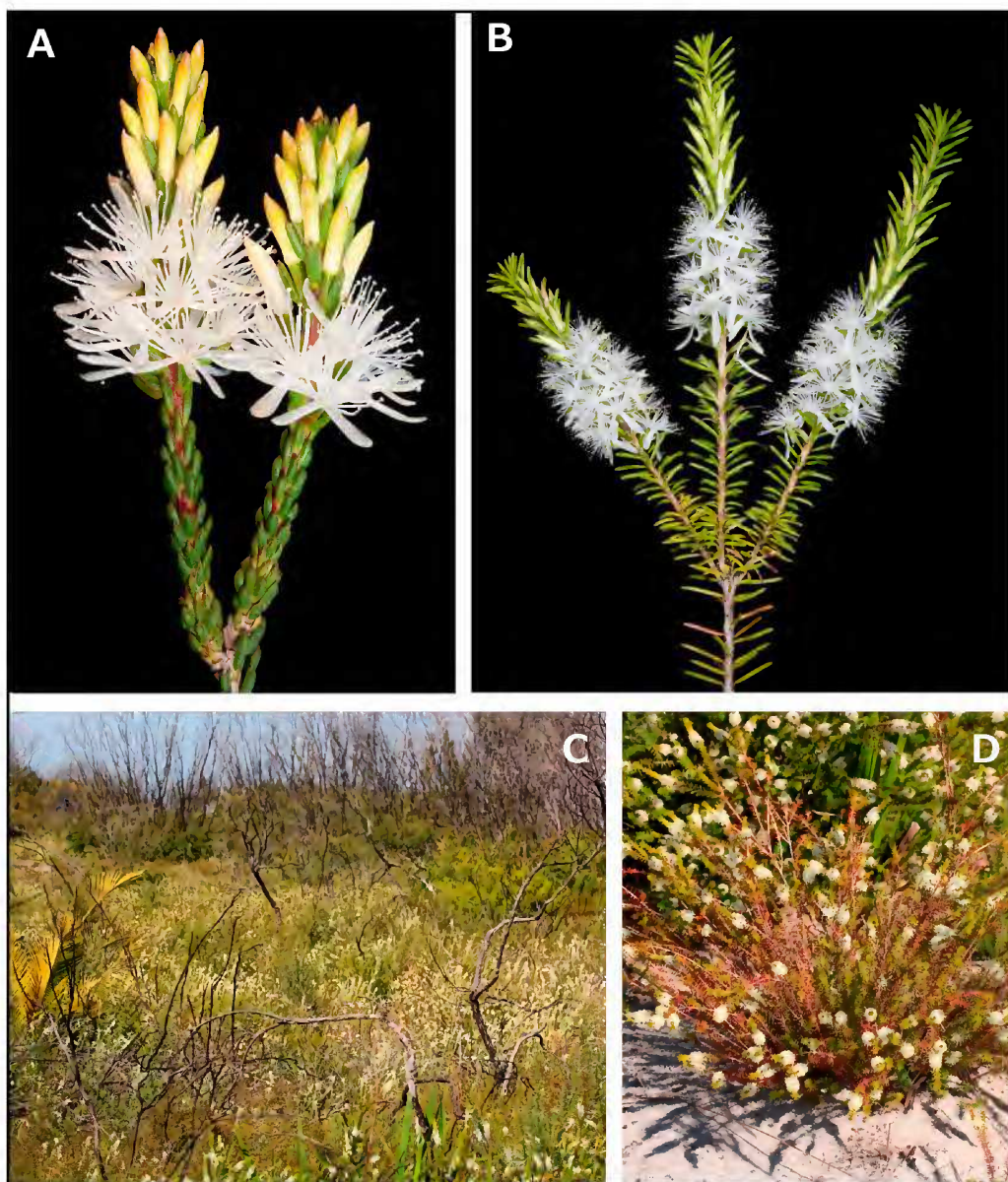


Figure 6. Morphology and habitat of study species. A – *Calytrix cravenii* Calingiri form (K.R. Thiele 4006); B – *C. hirta* (K.R. Thiele 5408); C – habitat of *C. hirta*; D – resprouting shrub of *C. hirta* (K.R. Thiele 5408). Photographs by K. Thiele (A, B) and F. Nge (C, D).

**Conservation status.** Not considered to be at risk; widespread throughout its range although many populations are found on road verges where little native vegetation remains.

**Typification.** Craven's (1987) type citation for *Lhotskya scabra* ('KW, holo.; K, W, iso.') comprises an inadvertent lectotypification of KW 1001262 under Art. 9.9 of the *International Code of Nomenclature for algae, fungi, and plants* (McNeill *et al.* 2012). The epithet *scabra* is pre-occupied in *Calytrix* by *C. scabra* DC.

*Etymology.* This species is named in honour of Dr Lyndley (Lyn) Alan Craven (1945–2014), a prominent figure in the Australasian plant systematic community who made substantial contributions to the field including a revision of the genus *Calytrix*.

*Affinities and notes.* *Calytrix cravenii* has the greatest variation in leaf and floral characters of all the members within the complex. Ciliate leaf margins are more prominent on *C. cravenii* than any other member in the complex. Most specimens in addition have leaf blades that are extensively covered in hairs. A few specimens (PERTH 04741854, PERTH 02157187, PERTH 04474058) have glabrous leaves. Whether these are only limited to the specimens collected or are consistent within their population requires further investigation. Northern populations of *C. cravenii* have more sparsely spaced cilia on their leaf blade margins, often increasing proximally to more strongly ciliate petioles. The hypanthium of *C. cravenii* is longer than most other members within the complex (with the exception of *C. acutifolia*), a feature that is often noticeable in the field.

Some collections from the Calingiri area have shorter leaves, petals and hypanthia than the typical form; however, typical specimens of *C. cravenii* have also been collected from near Calingiri (e.g. PERTH 01232649), close to populations of the Calingiri form. Further field observations (and perhaps molecular studies) are needed to establish whether these are phenotypic variants of a single variable taxon, or represent a distinct species; the Calingiri plants are here provisionally included in *C. cravenii* pending such studies.

***Calytrix hirta* (Regel) Nge & K.R.Thiele, *comb. nov.***

*Lhotskya hirta* Regel, *Gartenflora* 12: 337, t. 415, Figures 1–4 (1863). *Type citation*: ‘Entwickelt im Mai seine weissen Blumen und gedeiht bei gleicher Clatur, ve die Leptospermum-Arten und andere weniger zarte Neuhollander.’ *Type specimens*: Ex horto bot. Petropolitano [from a plant cultivated in a botanic garden at St Petersburg (Leningrad)], *leg. ign.* 66.4 (*lecto*: LE 00015414 image!, inadvertently designated by L. Craven, *Austral. Syst. Bot.* 10: 122 (1987); *syn*: Ex horto bot. Petropolitano, *leg. ign.* 63.5 (LE 00015416 image!)).

*Lhotskya ericoides* Schauer in J. Lindley, *Nat. Syst. Bot.* Edn. 2: 439 (1836). *Type citation*: ‘Hab. frequens in collibus circa sinum Regis Georgii III. in Novae Hollandiae ora australi-occidentali, ubi florentem legit Decembri M, 1821. All. Cunningham, qui sicca specimina benigne mecum communicavit.’ *Type specimen*: on the hills around King George Sound, Western Australia, Dec. 1821, *A. Cunningham* 232 (*syn*: MEL 545054 image!)

*Calytrix* sp. Esperance (M.A. Burgman 4268A), Western Australian Herbarium, in *FloraBase*, <https://florabase.dpaw.wa.gov.au/> [accessed 14 December 2016].

Multi-stemmed, spreading *shrubs* 0.5–2.5 m high. *Young stems* abundantly pilose with hairs 0.1–0.5 mm long, mottled cream and pale brown or smooth red-brown on new growth, with prominent leaf scars on older stems. *Leaves* alternate to partially subopposite; foliar colleters absent; petioles 0.5–0.7 mm long, yellow, glabrous; blades linear to slightly falcate, 3–11 mm long, 0.28–0.82 mm wide, depressed-angular-obovate in TS, glabrous to sparsely ciliate, with white-transparent hairs along the margins to 0.05 mm long; oil glands usually absent, sometimes noticeable; apex acute to obtuse. *Inflorescences* 20–80 mm long, 5–10 mm below shoot apex; peduncles *c.* 0.5 mm long; bracteoles green to light brown, glabrous to ciliate along midrib, 3–4 mm long, only connate at base, with entire margins and long-acuminate apex, translucent wings reduced and scarcely overlapping. *Flowers* 5-merous,

8–10(–13) mm diam.; hypanthium usually 6–8-ribbed, subcylindrical, (2–)2.5–3.5 mm long, smooth or rarely rugose between the ribs, sometimes slightly spotted, glabrous to finely ciliate, with hairs to 0.05 mm long; sepals 0.5–1.0 mm long, 0.2–0.8 mm wide, glabrous, the margin entire to slightly erose, the apex emarginate to obtuse-truncate, lacking awns; petals 4–5.5(–7) mm long, 0.8–1.5 mm wide, white (pale yellow in bud), glabrous; staminodes absent; stamens 32–46, white, 2-seriate, the longest filaments (3.5–)4–5 mm long, the anthers *c.* 0.3 mm long, cream to light yellow; style 4.5–5.5 mm long, white. *Seed* smooth, light cream-brown, narrowly obovoid, 1.5–2 mm long. (Figures 4D, 6B–D)

*Diagnostic features.* The following combination of characters can be used to differentiate *C. hirta* from other species within the complex: bracteoles with translucent wings reduced with hypanthium clearly visible; hypanthium > 2 mm (2.5–3.5 mm) long; longest pilose hairs along stems > 0.2 mm (usually to 0.5 mm long); leaf transverse section angular-obovate; leaf blades generally glabrous, few sparsely ciliate with indumentum < 0.05 mm long. The leaves of *C. hirta* are also perpendicular (patent) to the stem.

*Other specimens examined.* WESTERNAUSTRALIA: Denmark Block JQ136, 18 on Denmark River, 7 Dec. 1983, *A.R. Annels* 1760 (PERTH); East Mt Barren, 28 Oct. 1963, *T.E.H. Aplin* 2709 (PERTH); site 8C, Bibbulmun Track, Irwin Inlet - Boat Harbour Campsite, 29 Oct. 2001, *T. Evans* 783 (PERTH); Bremer Bay, 12 Oct. 1942, *C.A. Gardner* 6557 (PERTH); 1.5 m along track to Bluff Knoll from Chester Pass Rd, 15 Nov. 1959, *A.S. George* 434 (PERTH); near Boggy Lake, 6 miles SW of Walpole, 2 Dec. 1956, *J.W. Green* 1022 (PERTH); 9.6 km SE of Northcliffe–Windy Harbour Rd on Chesapeake Rd, 24 Oct. 1997, *B.J. Lepschi & B.A. Fuhrer* BJL 3653 (PERTH); *c.* 14.5 km SSE of Northcliffe, Mt Chudalup, 26 Nov. 1974, *B. Muir s.n.* (PERTH); Cape Naturaliste, 19 Sep. 1973, *E. Charles Nelson* ANU 17241 (CANB, PERTH); Wireless Hill, Esperance, 9 Oct. 1974, *B.L. Powell* 74117 (PERTH); Cape Arid National Park, E of Esperance, 1 Dec. 1971, *R. D. Royce* 9950 (PERTH); Two Peoples Bay Reserve, near Albany, Apr. 1975, *R.E.S. Sokolowski* 15/75 (PERTH); Cape Le Grand National Park, by Thistle Cove, 7 Nov. 1982, *A. Strid* 21220 (PERTH).

*Phenology.* Flowers from late September to late December, with a peak in late spring to early summer.

*Distribution and habitat.* Occurs in the Cape Naturaliste area, along the south coast from Walpole to Esperance, and inland to the Stirling Range (Figure 5). There are two main centres of distribution, from Walpole to Bremer Bay and from the Esperance area to Cape Arid National Park. Far-western populations growing on coastal dunes around Cape Naturaliste are disjunct from the main distribution. *Calytrix hirta* is commonly found on coastal to near-coastal dunes and on alluvial soils around granite outcrops. Four collections from the western end of the range are from river embankments or swamps, often next to granite. Associated vegetation includes low coastal heath, *Acacia* thickets, karri forest, *Eucalyptus* and *Agonis* open woodlands, and *Melaleuca* thickets.

*Conservation status.* Not considered to be at risk, widespread throughout the south coast with many populations currently protected under nature reserves.

*Typification.* Craven's (1987) type citation for *Lhotskya hirta* ('LE, holo.') comprises an inadvertent lectotypification under Art. 9.9 of the *International Code of Nomenclature for algae, fungi, and plants* (McNeill *et al.* 2012). The epithet of the first available name for this species (*L. ericoides* Schauer, 1836) is preoccupied in *Calytrix* by *C. ericoides* A.Cunn.



**Affinities and notes.** *Calytrix hirta* shares many characters with *C. retrorsifolia* Nge & Keighery, suggesting that they may be closely related. The longer and more prominent hairs (0.1–0.5 mm long) along their pilose stems in addition to shorter cilia (< 0.05 mm long) on their leaf margins distinguish them from other members of the complex. However, *C. hirta* has a longer hypanthium (2.5–3.5 mm *cf.* 1.5–2 mm in *C. retrorsifolia*), and leaves that are perpendicular to the stem as opposed to reflexed at maturity. The hypanthium of *C. retrorsifolia* is always shorter than the subtending bracteoles (cheridium), while in *C. hirta* it is subequal or longer. *Calytrix retrorsifolia* on average has shorter leaves (3.7–7.3 mm; mean = 4.5 mm) than *C. hirta* (3–11 mm; mean = 7.29 mm), although the range in leaf length overlaps. In addition, *C. hirta* is found in a wide range of habitats in contrast to the restricted range and habitat of *C. retrorsifolia* (confined to ironstones near Busselton).

Two leaf variants of *C. hirta* correspond with its two main areas of distribution. However, an interrupted cline is evident across the geographic disjunction between the two, with four geographically intermediate populations (three around Bremer Bay and one at East Mt Barren) having leaves that are intermediate between the two variants. Apart from these differences in leaf length and width, other characters examined are consistent throughout their range. Within the *C. acutifolia* species complex, *C. hirta* exhibits the greatest variation in the texture of its hypanthium. Hypanthia in most populations are smooth and strongly ribbed (similar to other members within the complex), with some populations (e.g. East Mt Barren, PERTH 02157098; Bremer Bay, PERTH 01953117, PERTH 06268579) having a spotted pattern. A few populations have smooth to slightly rugose hypanthia (e.g. D’Entrecasteaux National Park, PERTH 07887809; Yallingup, PERTH 07010753).

Four specimens collected from coastal dunes near Cape Naturaliste are disjunct by *c.* 100 km from the main area of distribution. They are more stunted in growth, and have shorter and thicker leaves than the typical western variant (Figure 2) and hypanthia that are shorter than the subtending bracteoles. In contrast to the green to brown hypanthia of other populations of *C. hirta*, these coastal populations have hypanthia that are light cream to pale brown (with the exception of one specimen, PERTH 02157373). The translucent wings of the bracteoles are more pronounced, covering up to half the hypanthium, and have strongly erose margins. We assume here that these differences are caused by their near-coastal habitat, but these populations are worthy of further study.

Potential pollinators of *C. hirta* were noted during field collection and observations taken during the course of this study. Flowering plants observed in November were often covered with beetles, primarily *Stenodorus suturalis* (Cerambycidae: Coleoptera) but also species from Mordellidae. *Stenodorus* were seen walking over fresh inflorescences and feeding on pollen. Unlike many other species of *Calytrix*, field observations indicate that *C. hirta* does not change its floral colour following successful pollination or after senescence (Lamont 1985).

***Calytrix retrorsifolia* Nge & Keighery, *sp. nov.***

**Type:** Tutunup, Western Australia [precise locality withheld for conservation reasons], 16 October 2001, G.J. Keighery & N. Gibson 2953 (*holo:* PERTH 06062075; *iso:* AD, CANB, K, MEL, NY).

*Calytrix* sp. Tutunup (G.J. Keighery & N. Gibson 2953), Western Australian Herbarium, in *FloraBase*, <https://florabase.dpaw.wa.gov.au/> [accessed 14 December 2016].

Slender, spreading, open *shrubs* 0.3–2 m high. *Young stems* abundantly pilose with hairs 0.1–0.5 mm long, mottled cream and pale brown or red-brown on new growth, with prominent leaf scars on older

stems. *Leaves* alternate to partially subopposite, reflexed at maturity on main stems below inflorescences; foliar colleterers absent; petioles 0.5–1 mm long, yellow, glabrous to slightly pubescent; blades linear to slightly falcate, 3.7–7.3 mm long, 0.3–0.45 mm wide, depressed-angular-obovate in TS, glabrous to sparsely ciliate with white-transparent hairs along the margins to 0.05 mm long; oil glands usually absent, sometimes noticeable; apex acute. *Inflorescences* 20–100 mm long, 5–10 mm below shoot apex; peduncles c. 0.5 mm long; bracteoles green to light brown, glabrous to ciliate along midrib, 1.5–3 mm long, only connate at base, with entire margins and long-acuminate apex, translucent wings reduced and scarcely overlapping. *Flowers* 5-merous, 8–9.5 mm diam.; hypanthium 5-ribbed, subcylindrical, 1.5–2 mm long, markedly rugose between the ribs, glabrous; sepals 0.3–0.6 mm long, 0.4–0.5 mm wide, glabrous, the margin entire, the apex rounded to obtuse-truncate, lacking awns; petals 4–5 mm long, 0.5–1.3 mm wide, white (pale yellow in bud), glabrous; staminodes absent; stamens 23–40, white, 2-seriate, the longest filaments 3–4 mm long, the anthers 0.2–0.3 mm long, light yellow; style 3.5–5 mm long, white. *Seed* not seen. (Figure 4C)

*Diagnostic features.* The following combination of characters can be used to differentiate *C. retrorsifolia* from other species within the complex: hypanthium distinctly rugose, with a reticulate-pitted texture; leaves reflexed at maturity; bracteoles always longer than the hypanthium; hypanthium 1.5–2 mm long; bracteoles with translucent wings reduced with hypanthium clearly visible; longest hairs along pilose stems > 0.2 mm (usually to 0.5 mm) long; leaf blade in transverse section angular-obovate; leaves generally glabrous, rarely sparsely ciliate with hairs < 0.05 mm long.

*Other specimens examined.* WESTERN AUSTRALIA: [localities withheld for conservation reasons] 27 Oct. 2008, *E. Bennett* 8/6 (PERTH); 3 Oct. 2001, *B. Jennings s.n.* (PERTH); 5 Oct. 2001, *B. Jennings per M. Soutar s.n.* (PERTH); 16 Oct. 2001, *G.J. Keighery & N. Gibson* 2953 (PERTH); 16 Oct. 2001, *G.J. Keighery & N. Gibson* 2956 (PERTH); 30 Oct. 1974, *G.S. McCutcheon* GSM 525 (PERTH); 25 Jan. 2001, *G.S. McCutcheon* 3018 (PERTH); 25 Jan. 2001, *G.S. McCutcheon* 3019 (PERTH).

*Phenology.* Flowers mostly in October.

*Distribution and habitat.* Restricted to shallow red clays and/or yellow sands over massive ironstones at the base of the Whicher Range south-east of Busselton (Figure 5). Plants are killed by fire and germinate prolifically the following winter forming dense stands of increasingly tall shrubs. Found in shrublands and *Eucalyptus* and *Banksia* woodlands. Associated species include *Grevillea elongata*, *G. manglesioides*, *Eucalyptus rudis*, *Banksia attenuata*, and *Jacksonia horrida*.

*Conservation status.* Listed by Smith (2017) as Priority Two under Conservation Codes for Western Australian Flora, as *C. sp.* Tutunup (*G.J. Keighery & N. Gibson* 2953). Highly restricted in range but locally abundant where it occurs. Currently known from two proposed nature reserves and a ‘flora road’ verge.

*Etymology.* The epithet is from the Latin *retrorsus* (turned or bent backwards) and *-folius* (-leaved), referring to the mature leaves that are closely retrorse on the stems.

*Affinities.* See under *C. hirta* for affinities and notes.

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